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Trials Lessons Learned: DRDC Ottawa Propagation Measurements and Support for DLCSPM Trials 9-10 January 06

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Abstract

This report presents a brief summary of lessons learned from experimental field trials conducted by Defence Research and Development Agency-Ottawa (DRDC Ottawa) from September 2005 to January 2006. The purpose of this report is to provide a record of trials-related issues and related procedural solutions which were found to work well, in order to advise the planning of similar future trials.

Thirteen separate items of advice are presented to improve confidence of success and efficiency, including inexpensive protection of test equipment from extreme cold, the use of visual signaling methods when radio communication is not possible, and the use of generators to provide electrical power at remote locations.

Résumé

Le présent compte rendu contient un bref résumé des leçons tirées des essais expérimentaux menés sur le terrain par Recherche et développement pour la défense Canada – Ottawa (RDDC-Ottawa), de septembre 2005 à janvier 2006. Le but du rapport est de produire un dossier qui renferme des problèmes liés aux essais et des solutions procédurales éprouvées, afin de guider la planification d’essais futurs similaires.

Treize recommandations distinctes sont proposées afin d’améliorer l’assurance de la réussite et l’efficacité des essais, notamment la protection peu coûteuse de l’équipement de mesure contre le froid extrême, l’utilisation de modes de communication visuelle lorsque la radiocommunication est impossible et l’utilisation de génératrices pour la production d’électricité dans les endroits éloignés.

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Executive summary

Trials Lessons Learned: DRDC Ottawa Propagation Measurements and Support for DLCSPM Trials 9-10 January 06

Charland, Shawn; DRDC Ottawa CR 2006-207; Defence R&D Canada – Ottawa; August 2006.

Introduction or background

This report presents a brief summary of lessons learned from experimental field trials conducted by Defence R&D Canada-Ottawa (DRDC Ottawa) from September 2005 to January 2006. The purpose of this report is to provide a record of trials-related issues and related procedural solutions which were found to work well, in order to advise the planning of similar future trials.

Results

This report presents solutions to field trials challenges related to adverse environmental effects on test equipment and personnel, the provision of prime power for test equipment, and sundry other issues. The report also addresses communication issues between various test sites and presents potential solutions. Several recommendations are made in the area of automation, rehearsals and test procedures, which will increase the efficiency, accuracy and confidence of success in trials activities.

Significance

The recommendations in this report will increase the efficiency, repeatability and accuracy of the measurements performed by the test team in all-weather conditions.

Future plans

No future work is planned in this area.

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Sommaire

Trials Lessons Learned: DRDC Ottawa Propagation Measurements and Support for DLCSPM Trials 9-10 January 06

Charland, Shawn; DRDC Ottawa CR 2006-207; R & D pour la défense Canada – Ottawa; August 2006.

Introduction ou contexte

Le présent compte rendu contient un bref résumé des leçons tirées des essais expérimentaux menés sur le terrain par R&D pour la défense Canada – Ottawa (RDDC Ottawa), de septembre 2005 à janvier 2006. Le but du rapport est de produire un dossier qui renferme des problèmes liés aux essais et des solutions procédurales éprouvées, afin de guider la planification d'essais futurs similaires.

Résultats

Le compte rendu propose des solutions à l'égard des essais sur le terrain dont les effets sont néfastes pour l'environnement, du problème de fourniture d'électricité pour l'équipement de mesure et de divers autres problèmes. Il porte également sur les problèmes de communications entre divers emplacements d'essai et propose des solutions. Plusieurs recommandations sont formulées dans le domaine de l'automatisation, des répétitions et du déroulement des essais afin d'accroître l'efficacité, la précision et l'assurance de la réussite des activités liées aux essais.

Importance

Les recommandations formulées dans ce rapport permettront d'accroître l'efficacité, la répétabilité et la précision des mesures réalisées par l'équipe d'essai, sans égard aux conditions météorologiques.

Perspectives

Aucun travail n'est prévu dans ce domaine.

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1. Introduction

This report presents a brief summary of lessons learned from experimental field trials conducted by Defence R&D Canada-Ottawa (DRDC Ottawa) from September 2005 to January 2006. The purpose of this report is to provide a record of trials-related issues and related procedural solutions which were found to work well, in order to advise the planning of similar future trials.

The trials experiences referenced in this report fall into two categories: propagation testing, and evaluation of commercial off-the-shelf (COTS) equipment. The relevant trials events are listed below:

1. short-range radio frequency (RF) propagation measurements conducted at DRDC Ottawa 22 Sept/05 - 4 Oct/05.
2. short-range RF propagation measurements conducted at a test range provided by the Royal Canadian Mounted Police (RCMP), in Ottawa, Ontario, 28 - 30 Nov/05.
3. field testing the performance of selected COTS equipment at the aforementioned RCMP test range, 9 - 10 Jan/06.

2. Overview of Trial Plans

2.1 Short Range Propagation Tests

Short range propagation tests involved using a gasoline powered vehicle to traverse a test range while carrying a RF transmitter and transmit antenna. A notionally identical receive antenna was placed at the centre of the test range, attached to a receiver. By measuring the RF power at the receiver and the location of the vehicle, patterns of constructive and destructive interference (propagation effects, also referred to as multipath) were measured. The equipment configuration and test range setup are presented in Figure 1.

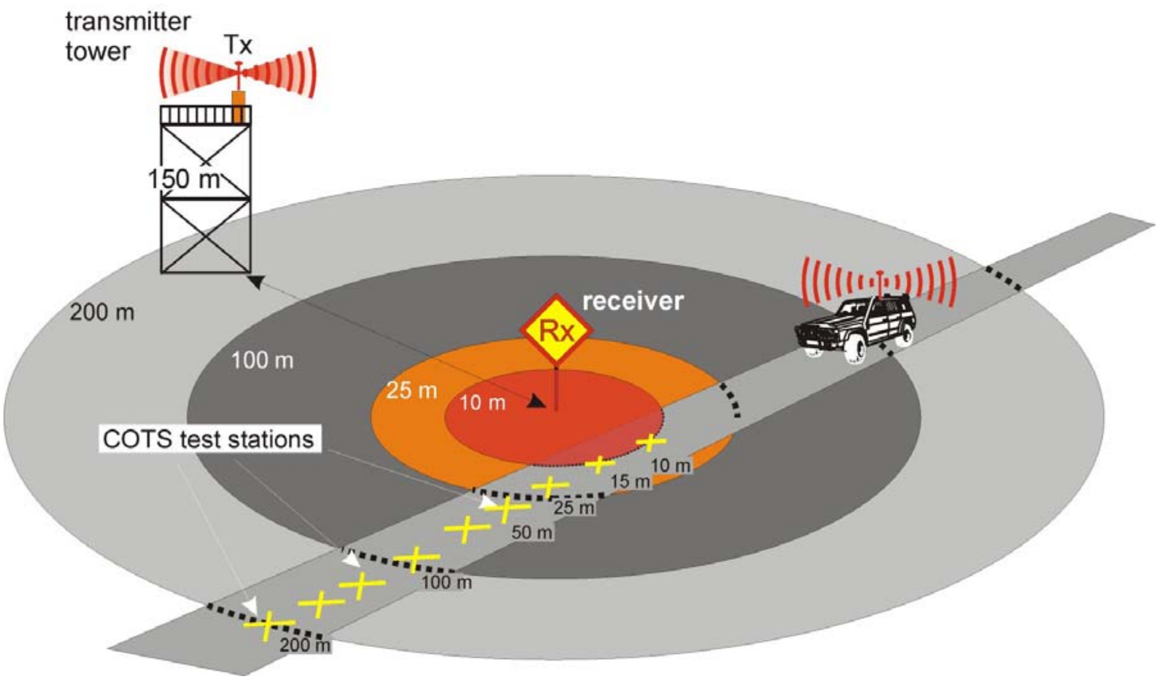


Figure 1: Test range for short-range propagation measurements.

2.2 COTS Equipment Evaluation

COTS equipment evaluation involved testing communications service between a transmitter-receiver pair (Tx-Rx pair). The receiver station was located at the centre of the test range. The associated transmitter was located on a tower 150 m from the receiver station. The COTS equipment was positioned on the test range at a specified distance from the receiver station and remained stationary for all tests. Tests involved following procedure:

1. Demonstrate and record communications performance of the Tx-Rx pair.
2. Activate the COTS system.
3. Demonstrate and record communications performance of the Tx-Rx pair.

3. Lessons Learned

3.1 Effect of Cold Weather Testing on Test Equipment

Issue: Some equipment stops working at low temperature, e.g. one Tx-Rx pair ceased functioning at an ambient air temperature of approximately -10 C.

Solution: Chemical heating pouches can be used with specially selected equipment enclosures (e.g. aftermarket camera bags) to hold test equipment (Figure 2).

Figure 2: Chemical heating pad with aftermarket camera case.

3.2 Instrumentation of Distance on Test Range

Issue: Vehicle position on the test range must be accurately measured in order to use propagation measurement data to validate software models. The required accuracy is dependent on radio frequency, vehicle position, transmitter and receiver antenna heights, ground conditions and the location of nearby scatterers. GPS position measurements were found to be insufficiently due to (a) poor repeatability and (b) insufficient accuracy.

Solution: GPS time was used as a reference for vehicle position and received RF power, in order to relate vehicle position and Rx power.

The vehicle was equipped with an electromechanical switch triggered by mechanical contact with bumpers laid at measured locations along the driving course (Figure 3).

(a) range bumpers

(b) vehicle-mounted switch

Figure 3: Electromechanical switch for range measurement

The switch was interfaced to a laptop computer equipped with a GPS time recorder. As the vehicle moved down the test range, GPS time was recorded by the laptop computer each time the switch was closed by contacting a range bumper. Rx power level at the receiver antenna was recorded simultaneously at approximately 6 Hz, with all measurements stamped with GPS time. Rx power level was thus correlated with vehicle position.

3.3 Reduction of Setup Time

Issue: Placement of range bumpers involves a significant labour effort to measure regular distances across the test range.

Solution: The road surface was marked with spray paint at each range bumper position. Because the test range is relatively long (240 m end-to-end), it was necessary to make approximate lateral measurements relative to the pavement edge to prevent sideways drift of the range positions (Figure 3 (a)). It is useful to mark the midpoint of the range bumper position on the road surface to allow the range bumpers to be easily aligned with each other on subsequent test days.

3.4 Repeatability of Measurements

Issue: There is a requirement to restore equipment at precise locations at the test site for repeated measurements to confirm and/or expand on earlier measurements.

Solution: Spray paint was used to mark the positions of range bumpers and the receiver station, and the nearby equipment van (Figure 4).

Figure 4: Vehicle position marking

3.5 Signalling Protocol During Testing

Issue: Communication is necessary between all trials participants in order to coordinate the participant's actions during testing. The principle participants are:

- Trials Director: responsible for execution of the test plan
- Communications Officer: responsible for initiating Tx-Rx communications
- COTS Officer: responsible for operating COTS equipment

A summary of communications signals between the Trials Director, the Communications Officer, and the COTS Officer is presented in Table 1.

Table 1: Summary of required coordinating communications during trials

From	To	Message
Trials Director	Communications Officer	Request to initiate Communications
Communications Officer	Trials Director	Confirmation of initiation of communications
Trials Director	Communications Officer	Request to cease communications
Communications Officer	Trials Director	Confirm Communications has ceased
Trials Director	COTS Officer	Request to activate COTS system
COTS Officer	Trials Director	Confirmation of activation of COTS system
Trials Director	COTS Officer	Request to deactivate COTS system
COTS Officer	Trials Director	Confirmation of deactivation of COTS system

The communications signals of Table 1are presented diagrammatically in Figure 5.

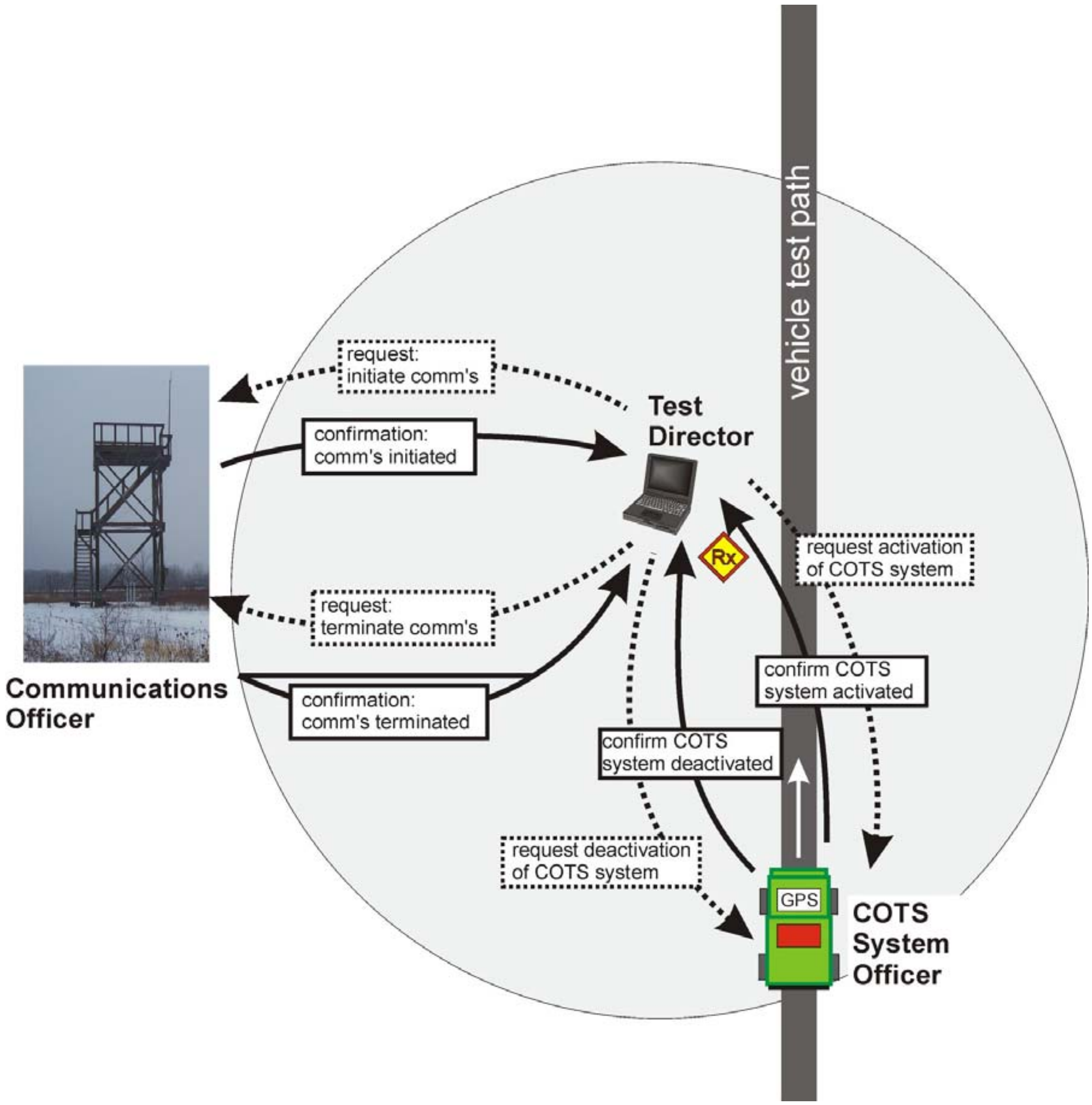


Figure 5: Communications requirements during trials

Communications during trials is complicated by a number of factors:

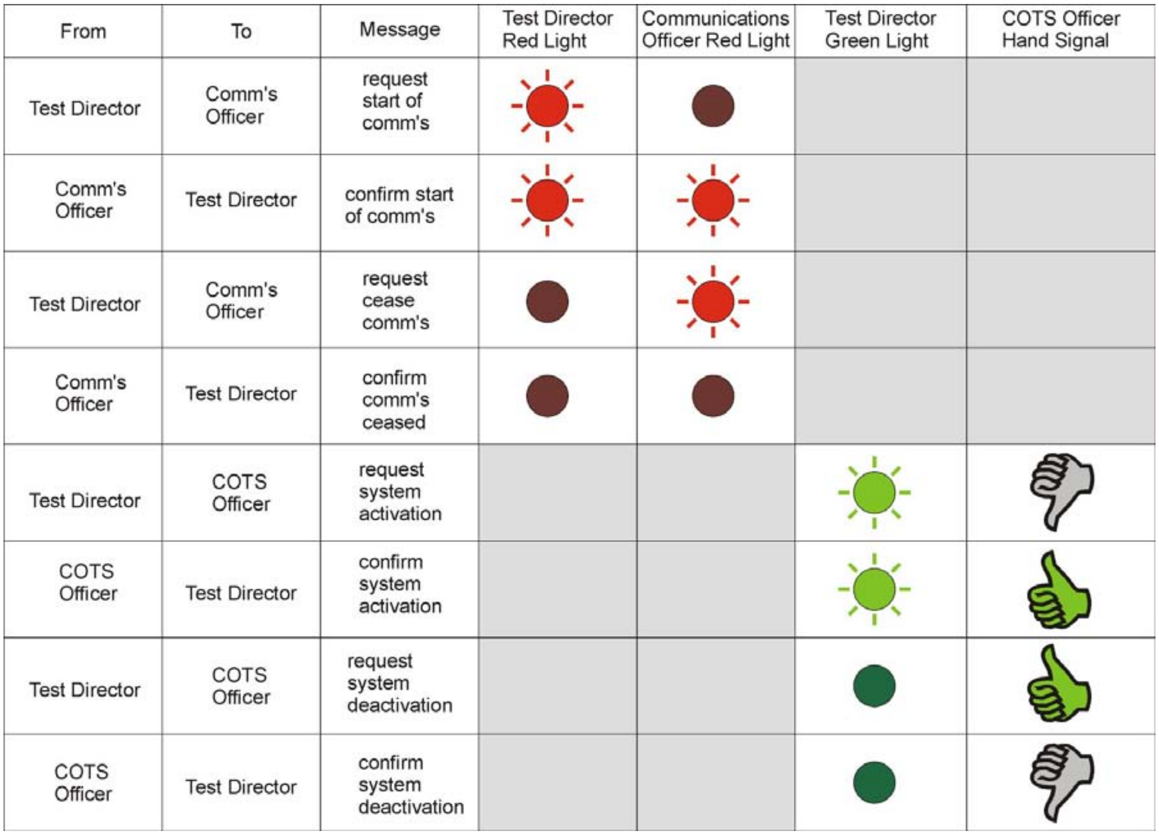
1. physical distance between trials personnel,
2. background acoustic noise (e.g. wind, electrical generators powered by gasoline motors), and
3. electromagnetic noise.

Unaided voice communication was found to be ineffective because of relatively large distances between trials personnel, and the proximity of one or both trials personnel to a source of acoustic noise. Radio communication was found to be ineffective because of the presence of electromagnetic and acoustic noise.

Solution: A combination of lights and hand signals were used for communication. The Test Director and Communications Officer communicated by each using a red coloured light (Figure 6). The Test Director communicated with the COTS Officer by using a green coloured light. The COTS Officer communicated with the Test Director by hand signals, since it was judged impractical for the System Officer to transport both a power supply for a light and the COTS system.

Figure 6: Lights used for communication between Test Directory and Communications Officer

The communication protocol is summarized in Figure 7.



From	To	Message	Test Director Red Light	Communications Officer Red Light	Test Director Green Light	COTS Officer Hand Signal
Test Director	Comm's Officer	request start of comm's				
Comm's Officer	Test Director	confirm start of comm's				
Test Director	Comm's Officer	request cease comm's				
Comm's Officer	Test Director	confirm comm's ceased				
Test Director	COTS Officer	request system activation				
COTS Officer	Test Director	confirm system activation				
Test Director	COTS Officer	request system deactivation				
COTS Officer	Test Director	confirm system deactivation				

Figure 7: Communication protocol

The protocol between the Trials Director and the Communications Officer depends on which of two types of communications are required for the test. These are:

1) Type 1: communications attempts are repetitive during an interval controlled by the Trials Director.

2) Type 2: a single communications attempt is requested by the Trials Director.

The communication sequence for Type 1 communications is:

1. Trials Director activates red light to request start of communications attempts.

2. Communications Officer activates red light to confirm communications attempts have begun.

3. Trials Director extinguishes red light to request that communications attempts cease.

4. Communications Officer extinguishes red light to confirm that communications attempts have ceased.

The communications sequence for Type 2 communications is:

1. Trials Director activates red light to request a communications attempt.

2. Communications Officer activates red light to confirm the start of a single communications attempt.

3. Communications Officer extinguishes red light to signal the completion of a single communications attempt.

4. Trials Director extinguishes red light to acknowledge that the communications attempt is complete.

3.6 Requirement for Assistants

Issue: The work load at the Trials Director and Communications Officer stations is sporadic but can be excessive, interfering with trials progress, effectiveness and efficiency. It is necessary to coordinate (a) signalling to request actions from various trials personnel,(b) execution of the requested actions, and (c) logging of actions and observations.

Solution: The Trials Director and Communications Officer each require an assistant. The assistant manages the signalling protocol, and maintains a written log of trials events and observations.

3.7 Provision for Remote Electrical Power

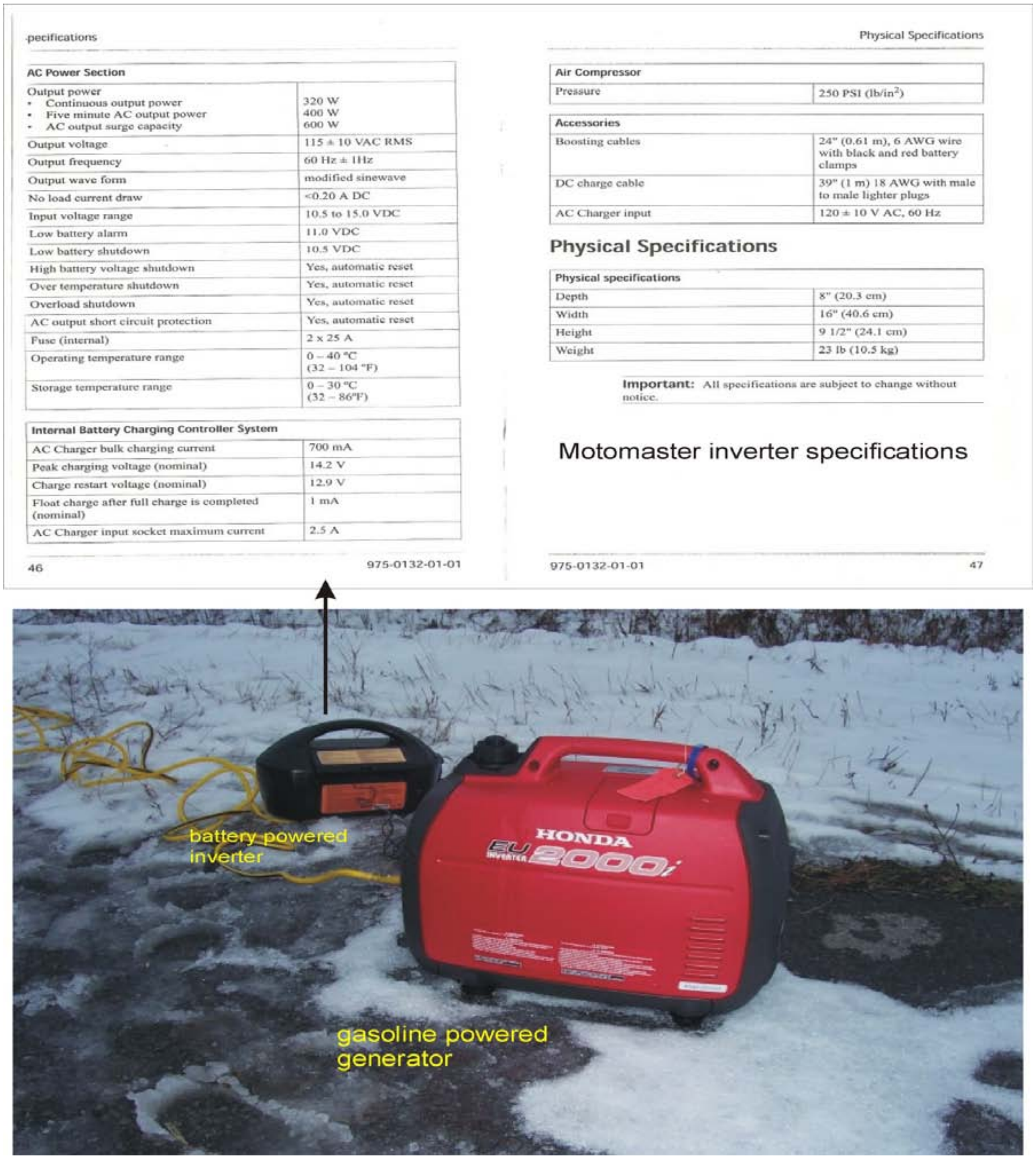
Issue: Electrical power is required on moving vehicle and at remote locations. The mobile test equipment comprises the following (Figure 8):

- HP Signal Generator 8648C (power consumption 170 VA, 120 V)
- Panasonic Toughbook CF-29 Laptop Computer, power supply model CF-AA1653A, (120v/1.2A)

Toughbook power supply specifications

Figure 8: Mobile test equipment

A small gasoline powered generators (Honda EU2000i, Figure 9) was found to work well for stationary testing, but movement can caused it to turn itself off, possibly due to false indications of low oil level caused by sloshing in the oil reservoir.



pecifications

AC Power Section	
Output power • Continuous output power • Five minute AC output power • AC output surge capacity	320 W 400 W 600 W
Output voltage	115 ± 10 VAC RMS
Output frequency	60 Hz ± 1Hz
Output wave form	modified sinewave
No load current draw	<0.20 A DC
Input voltage range	10.5 to 15.0 VDC
Low battery alarm	11.0 VDC
Low battery shutdown	10.5 VDC
High battery voltage shutdown	Yes, automatic reset
Over temperature shutdown	Yes, automatic reset
Overload shutdown	Yes, automatic reset
AC output short circuit protection	Yes, automatic reset
Fuse (internal)	2 x 25 A
Operating temperature range	0 – 40 °C (32 – 104 °F)
Storage temperature range	0 – 30 °C (32 – 86°F)

Internal Battery Charging Controller System	
AC Charger bulk charging current	700 mA
Peak charging voltage (nominal)	14.2 V
Charge restart voltage (nominal)	12.9 V
Float charge after full charge is completed (nominal)	1 mA
AC Charger input socket maximum current	2.5 A

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Physical Specifications

Air Compressor	
Pressure	250 PSI (lb/in^2)

Accessories	
Boosting cables	24" (0.61 m), 6 AWG wire with black and red battery clamps
DC charge cable	39" (1 m) 18 AWG with male to male lighter plugs
AC Charger input	120 ± 10 V AC, 60 Hz

Physical Specifications

Physical specifications	
Depth	8" (20.3 cm)
Width	16" (40.6 cm)
Height	9 1/2" (24.1 cm)
Weight	23 lb (10.5 kg)

Important: All specifications are subject to change without notice.

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Figure 9: Portable power supplies unsuitable for mobile testing

A battery powered inverter (Motomaster Eliminator Power Box, Figure 9) was able to power the mobile test equipment, but could provide only 15 minutes of test time. The short duration is primarily due to the relatively high power consumption of the signal generator.

Solution: A large-size gasoline powered generator (Honda EM500S, Figure 10) was found to be suitable for use in the moving vehicle, provided the road surface was level.

Figure 10: Large size gasoline powered generator suitable for mobile testing

3.8 Data Recording

Issue: Propagation measurements require RF power levels to be recorded at various frequencies. The sampling rate must be sufficient that the range separation of power measurements is close enough to resolve the structure of multipath interference. The required sampling rate depends on vehicle speed and antenna geometry.

Solution: Spectrum Explorer (Figure 11) was used to record the RF power level at the receive antenna. The update rate was approximately 160 ms. For a nominal vehicle speed of 4 kph (1.11 m/sec), the ground spacing of samples was approximately 0.18 m.

Figure 11: Spectrum Explorer RF signal recording system

3.9 Constant Vehicle Speed

Issue: The vehicle used in propagation measurements was a John Deere Gator (Figure 12). Vehicle speed and data sampling rate determines spatial separation of propagation data points. Slow constant speed is desirable since vehicle position must be inferred from a combination of GPS time stamps and ground-truth vehicle location data, intermittently provided by range bumpers (section 3.2). This approach requires the vehicle speed to be approximately constant between range bumpers. The test vehicle speed could not be controlled with sufficient accuracy using the accelerator pedal.

Figure 12: Vehicle used in propagation measurements

Solution: The Gator's maximum speed can be limited by adjusting the position of a manufacturer-supplied bolt (Figure 13) under the accelerator pedal. The bolt limits the maximum depressed pedal position, limiting the maximum demanded speed. However, analysis of trials data indicates that there is a small but tolerable (i.e. roughly linear between range bumpers (section 3.2)) residual acceleration even with the pedal depressed to the limit.

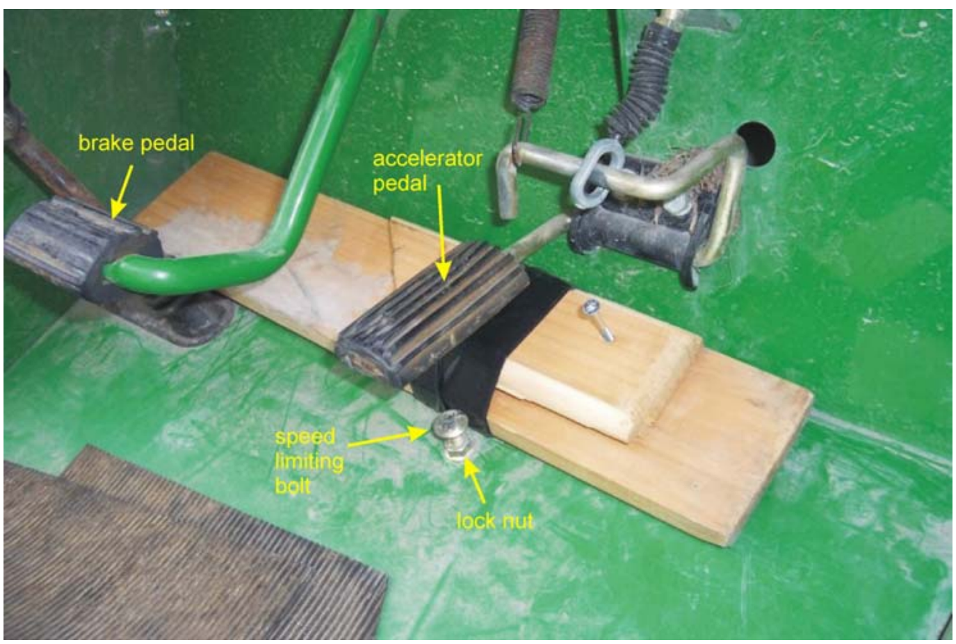

Figure 13: Speed limiting bolt in Gator

3.10 Requirement for Environmental Enclosures

Issue: Some test team members and test equipment are stationary during trials, and can be exposed to harsh environmental conditions. Shielding is required from wind, precipitation and sun.

Solution: Temporary environmental enclosures are recommended to mitigate wind, precipitation, and sun. Environmental enclosures must be large enough to house the test team, visitors, and equipment. Enclosures are required at both transmit and receive stations. Examples of commercially available environmental enclosures are presented in Figure 14.

Figure 14: Commercially available environmental enclosures

3.11 Photography

Issue: Precise information regarding equipment configuration may be necessary during post-trials data analysis. This information may also be critical in allowing various tests to be repeated for verification. This information includes surface conditions during propagation measurements, location and orientation of antennas, specific test equipment used, arrangement of cabling and equipment layout, local environment, weather conditions during testing, etc.

Solution: A camera is required during all trials for documentation of trials setup and conduct, as well as unanticipated photos of opportunity. Additionally, the DRDC Ottawa photo unit can provide these services. Photography has the potential to provide a complete and objective record of the physical elements of the trial.

3.12 Importance of Rehearsals

Issue: Trials schedules become jeopardized if setup, conduct, or cleanup times exceed allocated time budgets.

Solution: Trials setup, execution and cleanup times can be dramatically reduced by rehearsing procedures. Equipment inventory check lists can reduce the risk of delays caused by the need to recover missing equipment. Procedure check lists can reduce the risk of delays caused by incorrect equipment configuration or procedural errors.

3.13 In-House Personnel Resources

Issue: Trials can require new procedures to deal with unexpected environmental conditions, data generation and/or recording functions, equipment configuration, etc.

Solution: There is considerable in-house expertise in various areas including cold-weather testing, hot weather testing, as well as photographic and graphics support.

4. Conclusion

This report summarizes lessons learned regarding RF propagation measurements and commercial off-the-shelf (COTS) equipment testing. Issues and recommended solutions are presented below.

4.1 Effect of Cold Weather Testing on Test Equipment:

Issue: Some equipment stops working at low temperature (one example at -10 C).

Solution: Use environmental enclosures and chemical warmers to keep vulnerable equipment warm.

4.2 Instrumentation of Distance on Test Range:

Issue: Vehicle position on the test range must be accurately measured.

Solution: A vehicle mounted mechanical switch, range bumpers and GPS time synchronization were used to establish vehicle position.

4.3 Reduction of Setup Time:

Issue: Placement of range bumpers involves a significant labour effort to measure regular distances across the test range.

Solution: The road surface was marked with spray paint at each range bumper position.

4.4 Repeatability of Measurements:

Issue: Restoration of test equipment at precise locations at the test site for repeated measurements to confirm and/or expand on earlier measurements.

Solution: Mark the equipment positions using spray paint.

4.5 Signalling Protocol During Testing:

Issue: Communication is necessary between all trials participants in order to coordinate the participant's actions during testing.

Solution: A system of lights and hand signals was used to implement a communications protocol.

4.6 Requirement for Assistants:

Issue: The work load at the Trials Director and Communications Officer stations is sporadic but can be excessive, interfering with trials progress, effectiveness and efficiency.

Solution: The Trials Director and Communications Officer each require an assistant.

4.7 Provision for Remote Electrical Power:

Issue: Electrical power is required on moving vehicle and at remote locations.

Solution: A large-size gasoline powered generator (Honda EM500S, fig. 3.7-3) was found to be suitable for use in the moving vehicle, provided the road surface was level.

4.8 Data Recording:

Issue: It is necessary to record RF power levels at various frequencies.

Solution: Spectrum Explorer was used to record the RF power level at the receive antenna.

4.9 Constant Vehicle Speed:

Issue: The test vehicle speed could not be controlled with sufficient accuracy using the accelerator pedal.

Solution: The vehicle's maximum speed was limited by adjusting the position of a manufacturer-supplied bolt under the accelerator pedal.

4.10 Requirement for Environmental Enclosures:

Issue: Some test team members and test equipment can be exposed to harsh environmental conditions; shielding is required from wind, precipitation and sun.

Solution: Temporary environmental enclosures are recommended to mitigate wind, precipitation, and sun.

4.11 Photography:

Issue: Precise information may be necessary during post-trials data analysis regarding equipment configuration.

Solution: Bring a camera to all trials for incidental photos of opportunity and photograph everything.

4.12 Importance of Rehearsals:

Issue: It is generally necessary to economize time on the test range.

Solution: Trials setup and execution times can be dramatically reduced by rehearsing procedures.

4.13 In-House Personnel Resources:

Issue: Trials often require that new procedures be developed to deal with unexpected environmental conditions, data generation and/or recording functions, equipment configuration,

Solution: There is considerable in-house expertise in various areas including cold-weather testing, hot weather testing, as well as photographic and graphics support.

List of symbols/abbreviations/acronyms/initialisms

C	celsius
COTS	Commercial Off-the-Shelf
DRDC	Defence Research and Development
GPS	Global Positioning System
kph	Kilometres per hour
RCMP	Royal Canadian Mounted Police
RF	Radio frequency
Rx	Receive
Tx	Transmit

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This report presents a brief summary of lessons learned from experimental field trials conducted by Defence Research and Development Agency-Ottawa (DRDC Ottawa) from September 2005 to January 2006. The purpose of this report is to provide a record of trials-related issues and related procedural solutions which were found to work well, in order to advise the planning of similar future trials.

Thirteen separate items of advice are presented to improve confidence of success and efficiency, including inexpensive protection of test equipment from extreme cold, the use of visual signaling methods when radio communication is not possible, and the use of generators to provide electrical power at remote locations.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

trials, lessons learned, propagation